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MEMORANDUM FOR PRS (In-House Contractor Publication)

FROM: PROI (STINFO) 17 May 2002

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2002-114** David Kirtley (ERC) and John Fife (PRSS), "Modeling, Simulation, and Design of an Electrostatic Colloid Thruster" (Viewgraphs only)

29th IEEE International Conference on Plasma Science **(Statement A)**
(Banfe, Alberta, Canada) (Deadline: 26 May 2002)

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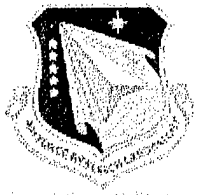


Modeling, Simulation, and Design of an Electrostatic Colloid Thruster

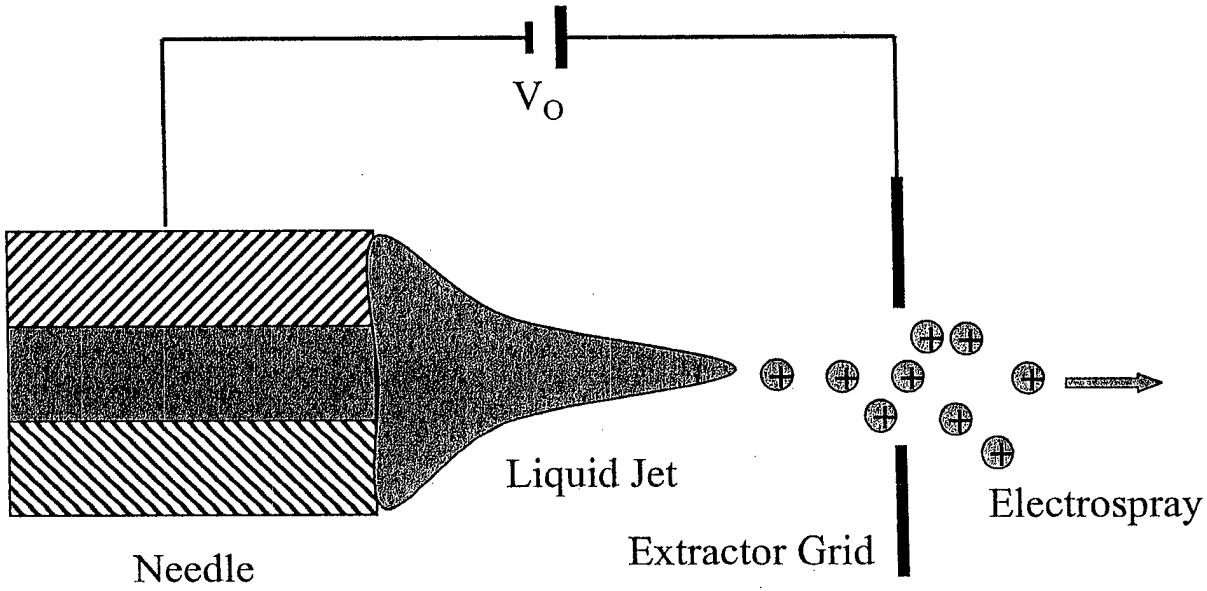
David Kirtley

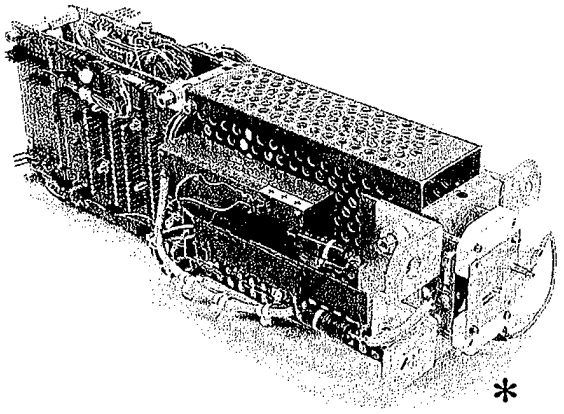
J. M. Fife

28 May 2002

- Colloid Introduction
- Design Process
  - OTS Modeling, Simulation
- Particle Tracking Analysis
- Non-Ideal Acceleration Voltages
  - Turn-On, Turn-Off, Dispersion, Off-Axis
- Preliminary Extraction Models
- Performance Optimization

Colloid Introduction



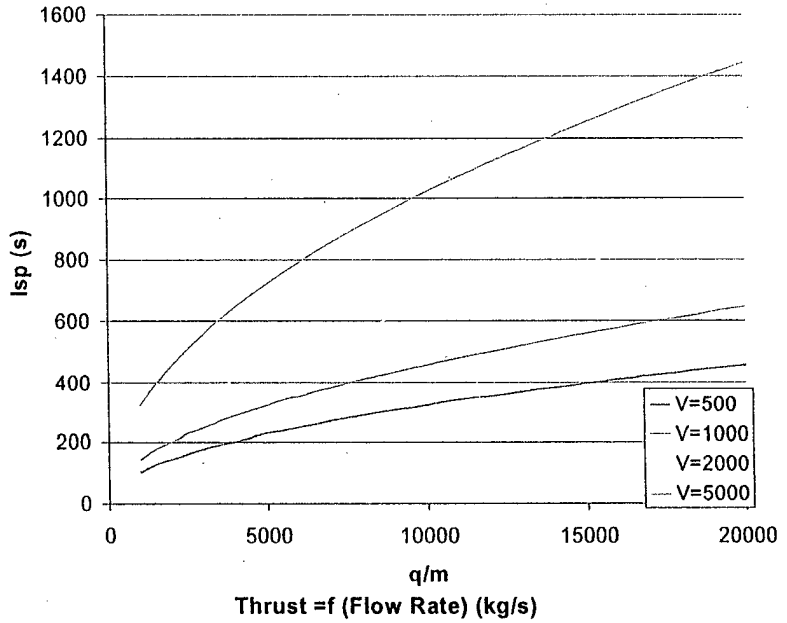


- Colloid Engine Theory:
  - —Particles with Large mass/charge enable higher thrust density Ion (electrostatic) engines
  - —Use electric fields to extract charged high-conductivity liquid droplets (electro-spray)
  - —Accelerate particles at high velocities (up to 1500s) and high efficiency (to 90%)
  - —Arrays of small needles that each provide small thrust (μN's) with capillary feed systems
  - —No sheath/ionization losses/complications

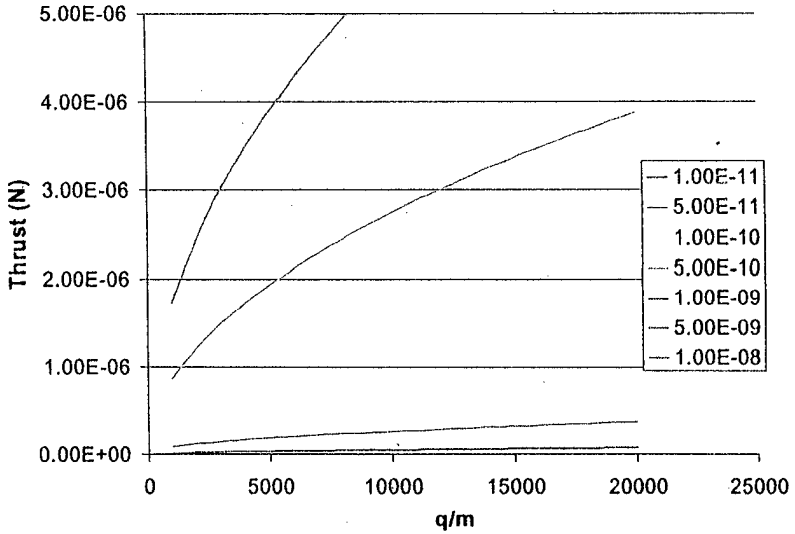
Design Process

Design Thrusters, Not Electrospray

- Work Backwards
- Locate Missions
  - Performance Characteristics
- Design Acceleration System
  - quantify loss mechanisms
- Design Extraction System
  - Flow system, extraction voltages,
- Optimize design variables

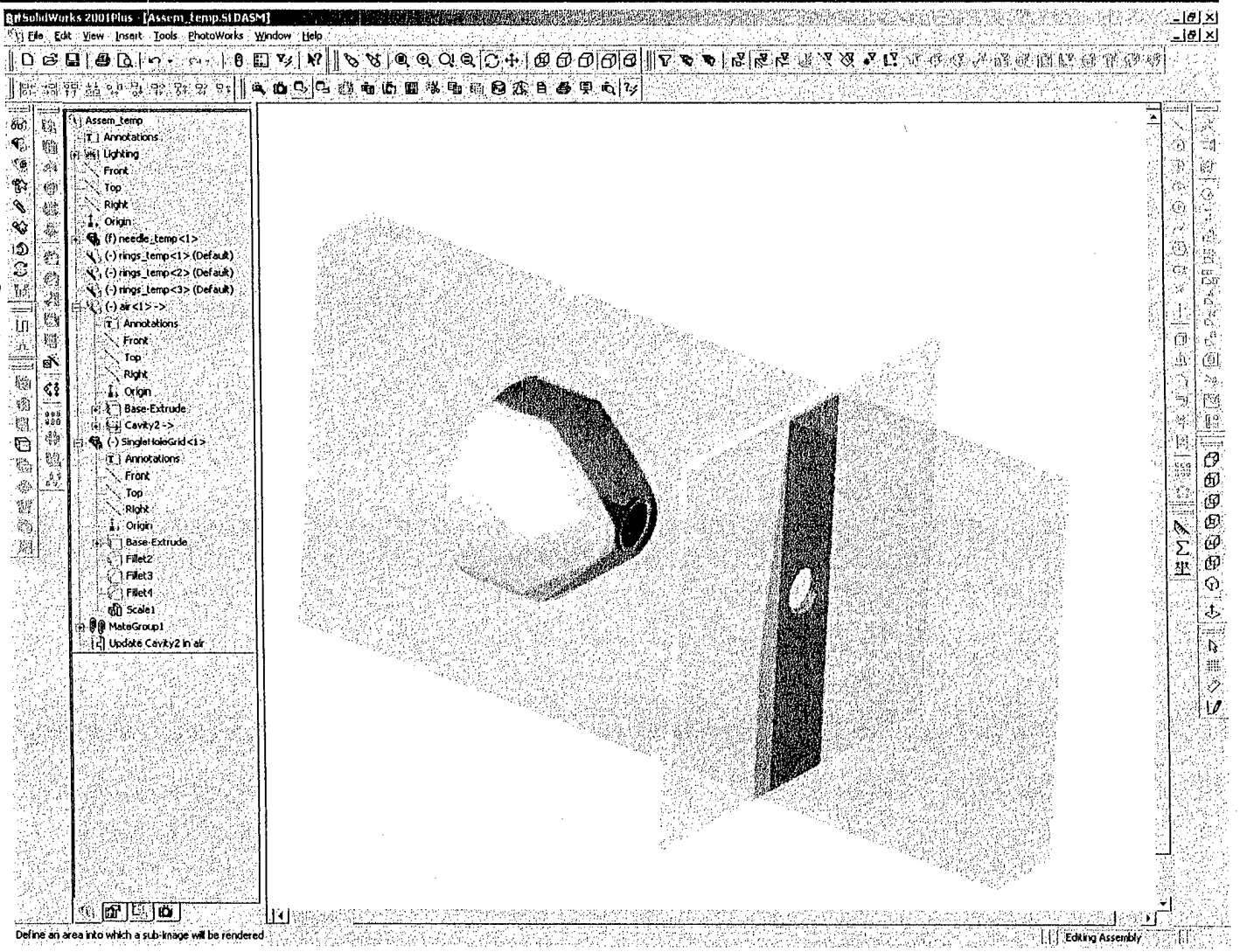


Thrust =f (Flow Rate) (kg/s)



Off-The-Shelf Modeling, Simulation

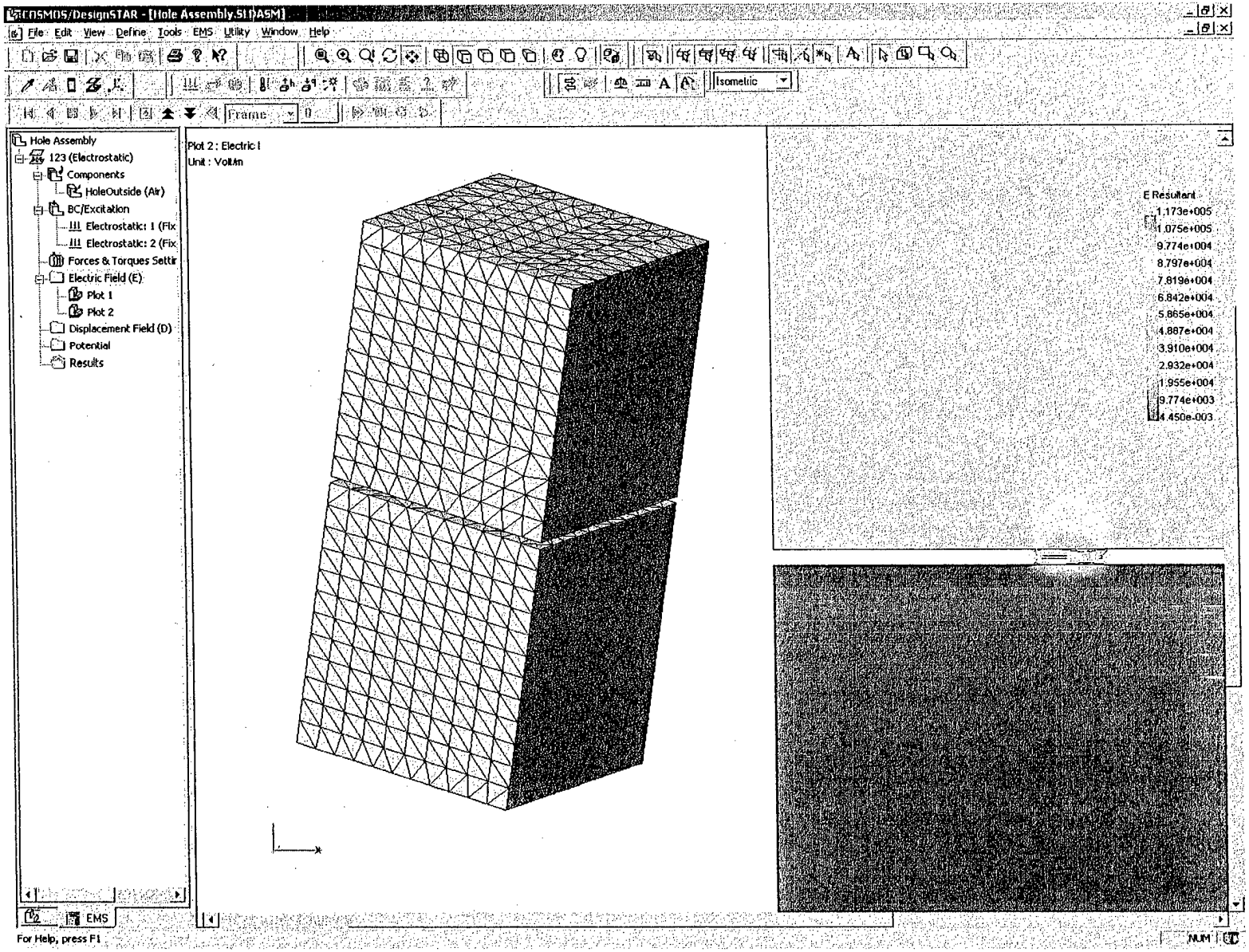
Use OTS 3D Modeling, Grid Generation, Electrostatic Solvers to speed/cheapen thruster design and simulation



SOLIDWORKS COLLOID MODEL

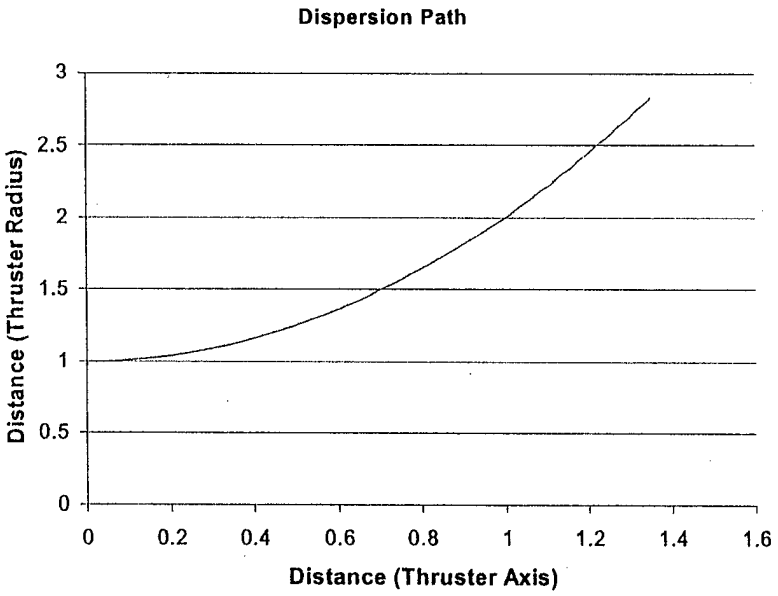
Off-The-Shelf Modeling, Simulation

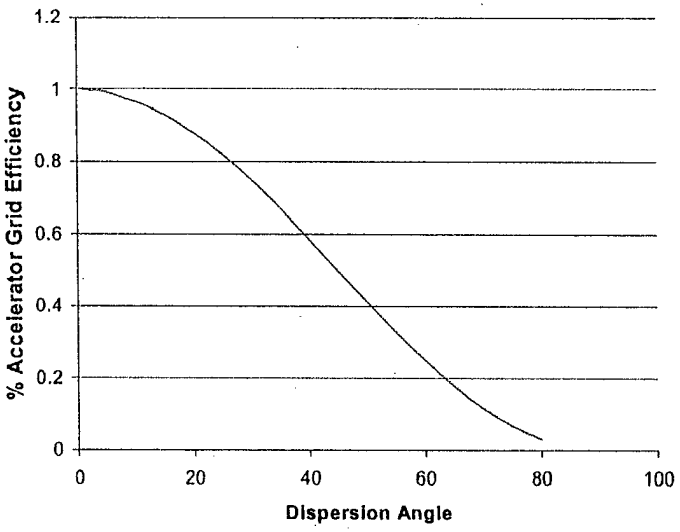
COSMOSWORKS
EMS Gridding



Particle Tracking Analysis

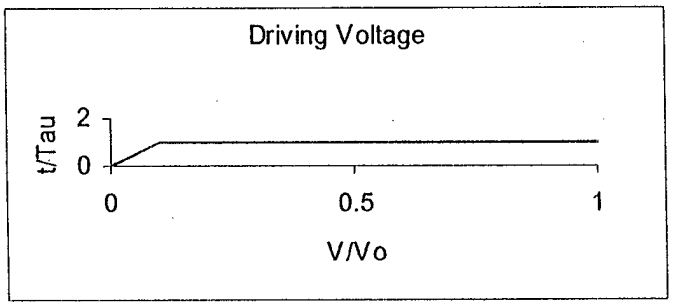
- Straight Dispersion Prediction
- E-field shaping models
- Acceleration/Efficiency losses due to non-uniform E-fields, grids



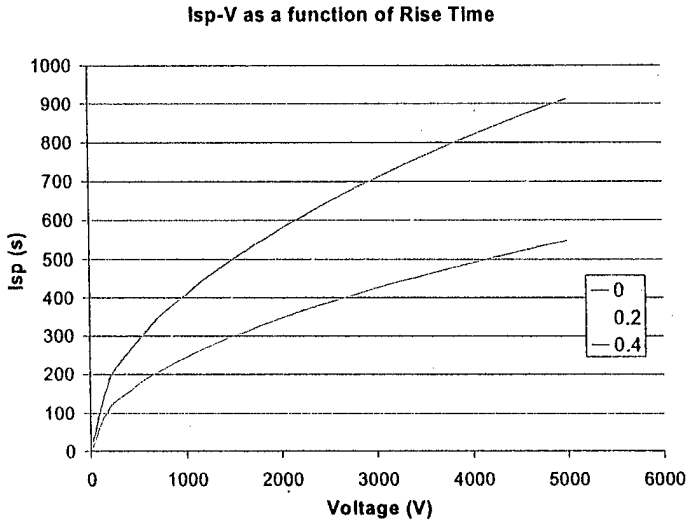


Performance Losses

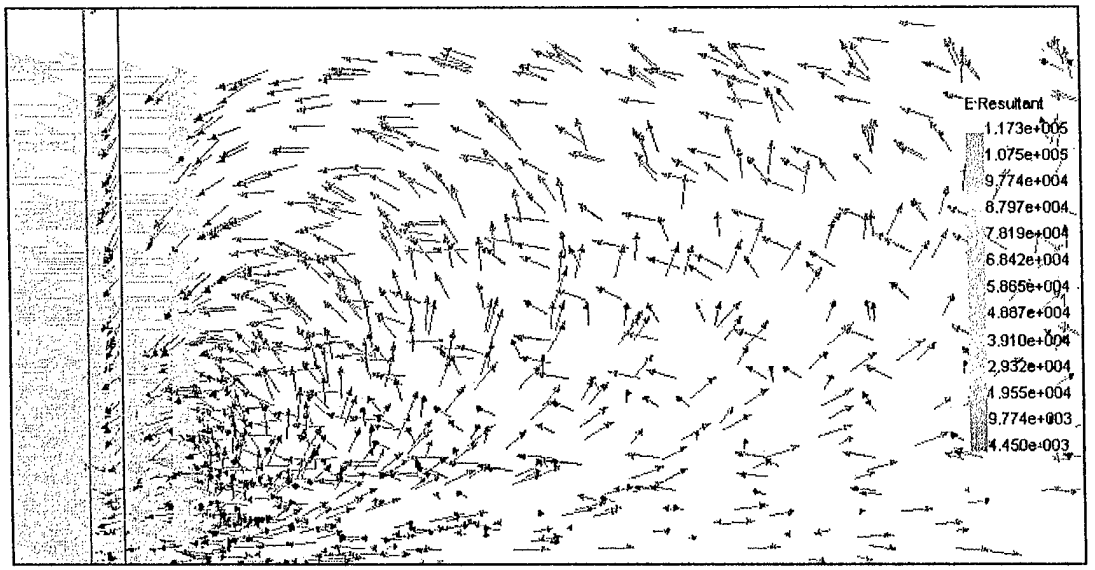
- Turn-On, single droplet



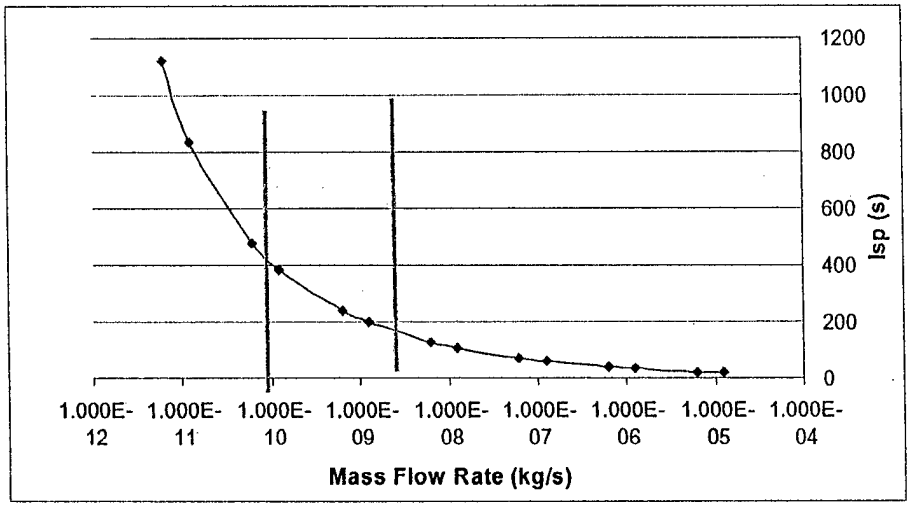
$$x(t) = \frac{q}{m}\Delta x\left(Mt^2{}_{rise} * t + V\left(t^2/_2 - t * t_{rise}\right)\right)$$



- E-field Incongruities at Interface
  - Highly situation dependent
  - Developed analysis system for individual cases



Extractor Modeling

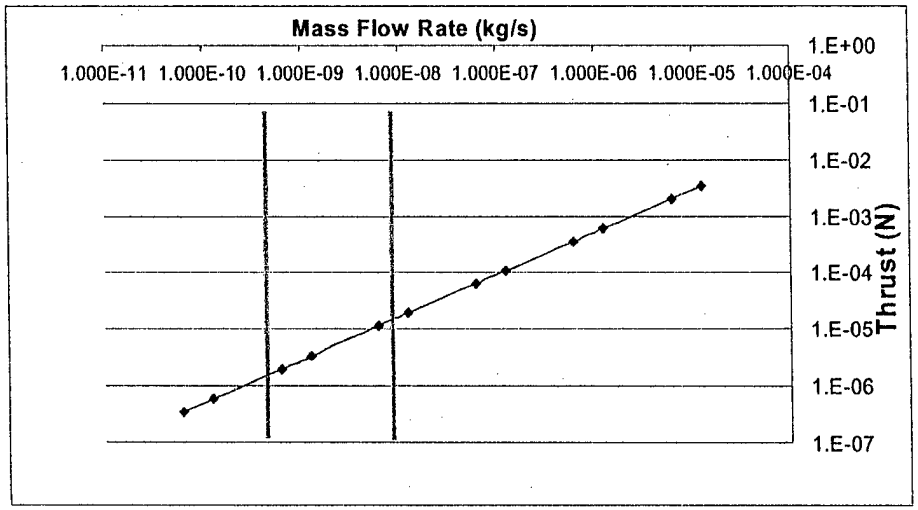


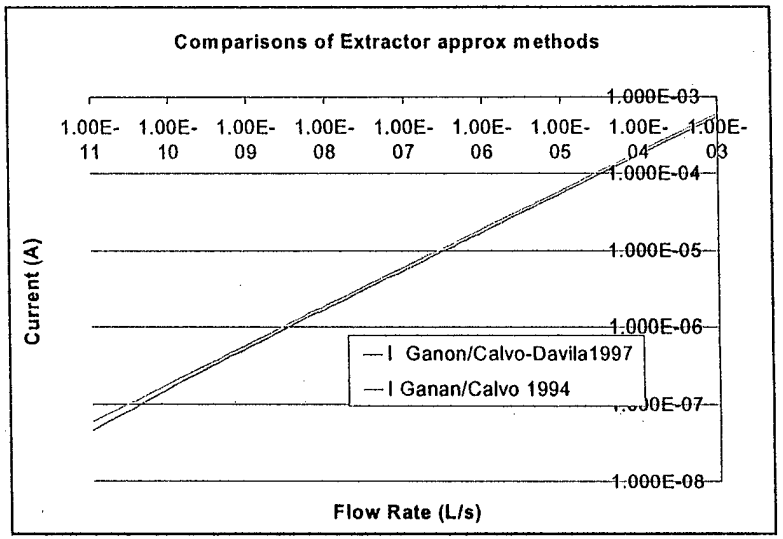
Ganan-Calvo 1997,1994

De La Mora and Loscertales 1993

$$\frac{I}{I_0} = 6.2\left[\frac{Q}{(\beta-1)^{1/2}Q_0}\right]^{1/2} - 2.0$$

$$\frac{d}{d_0(\beta-1)^{1/3}} = 1.6\left[\frac{Q}{(\beta-1)^{1/2}Q_0}\right]^{1/3} - 1.0$$





Conclusion

- Presented is a modeling design process for a colloid micro-thruster
- Acceleration Grid Effects
- Extractor Grid Effects
- Performance Predicting, Optimization

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